(12) UK Patent Application (19) GB (11) 2 028 062 A

(21) Application No 7833621
(22) Date of filing 17 Aug 1979
(23) Claims filed 17 Aug 1979
(43) Application published 27 Feb 1980
(51) INT CL³ H04L 9/02
(52) Domestic classification H4P CD PL H4L UM
(56) Documents cited GB 889347
(58) Field of search G1A G5X H4L H4P

(71) Applicants
Standard Telephones and Cables Limited,
190 Strand, London
W.C.2. England
(72) Inventors
Martin Chown
Jeffrey Graham Farrington
Richard Gordon Samuel Plumb
(74) Agent
S. R. Capsey

(54) Data transmission system

(57) In a closed-loop data transmission system, the terminals 1-6 of the system each send round the loop a message formed by service data and a random bit stream. Each such message is sent in a time position in a time division cycle individual to that terminal.

When such a message reaches a terminal with a data message to be sent to the originating terminal that data message is encoded into the random bit stream: the now-encoded message continues round the loop in the same direction until it reaches the originating terminal where it is received and decoded.

To improve system security, in addition to the links which interconnect adjacent terminals in the loop there are so-called leap-frog links each of which extends from one terminal to the next but one terminal in the loop.

The invention is described in its application to a system in which the links are optical fibre cables, but the invention is also applicable where the links are of the metallic wire type.

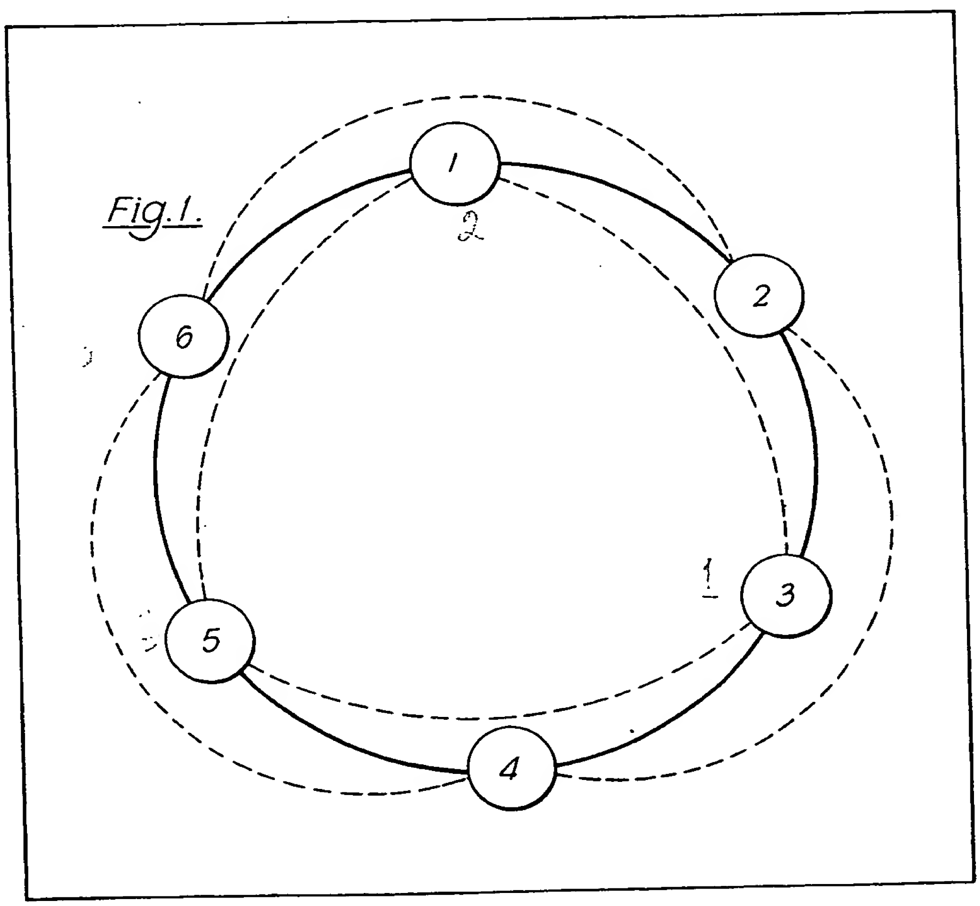


Fig.1.

GB 2 028 062 A

Fig.1.

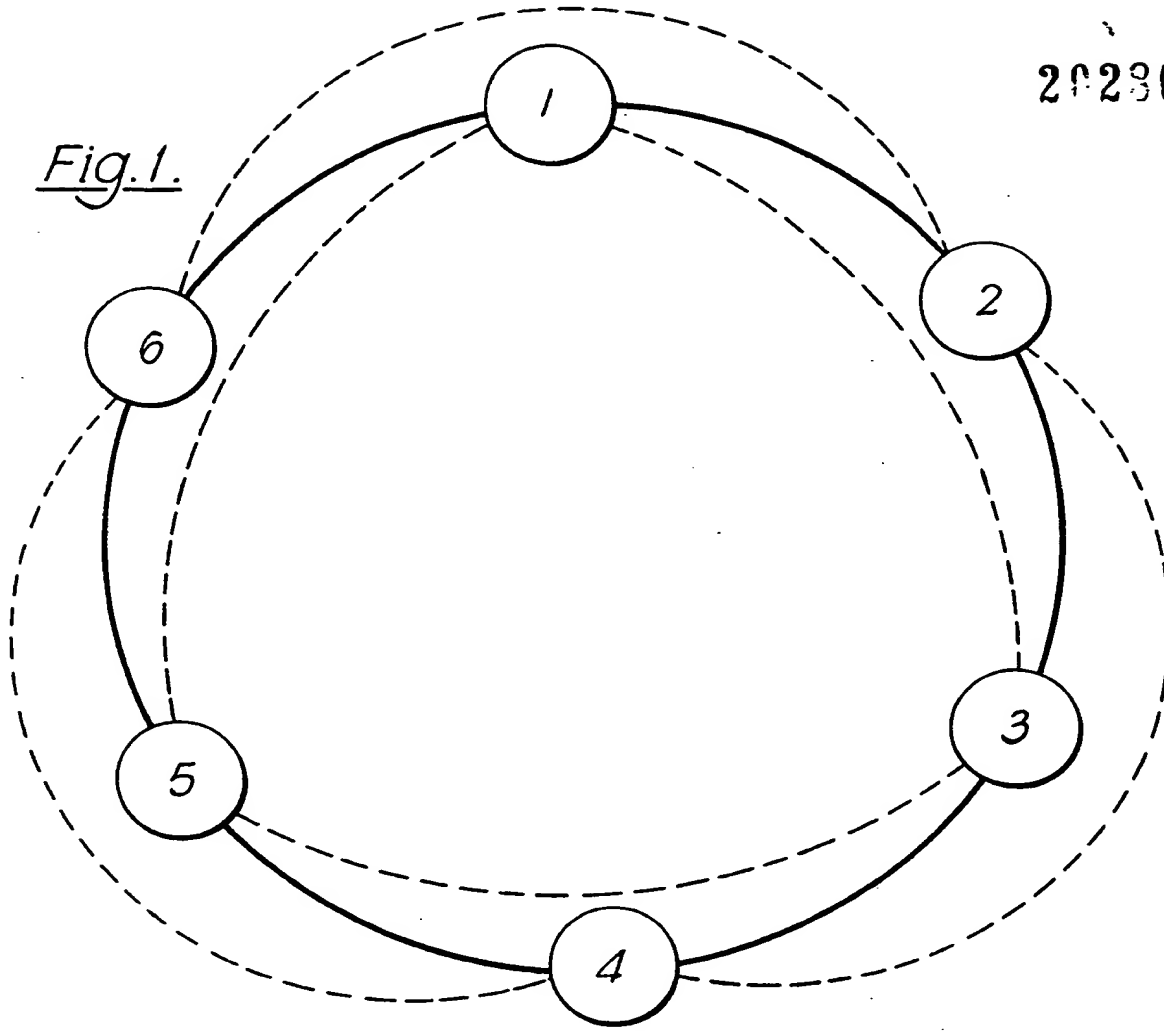


Fig.2.

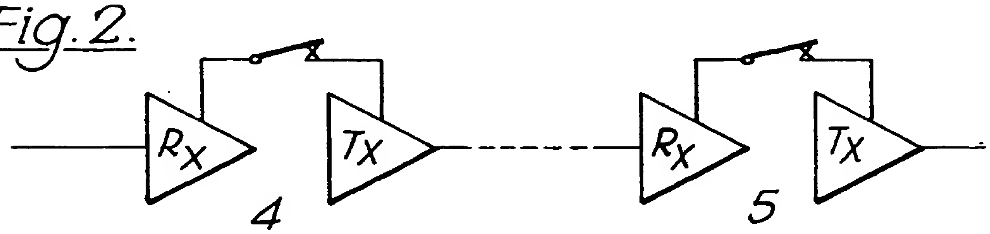
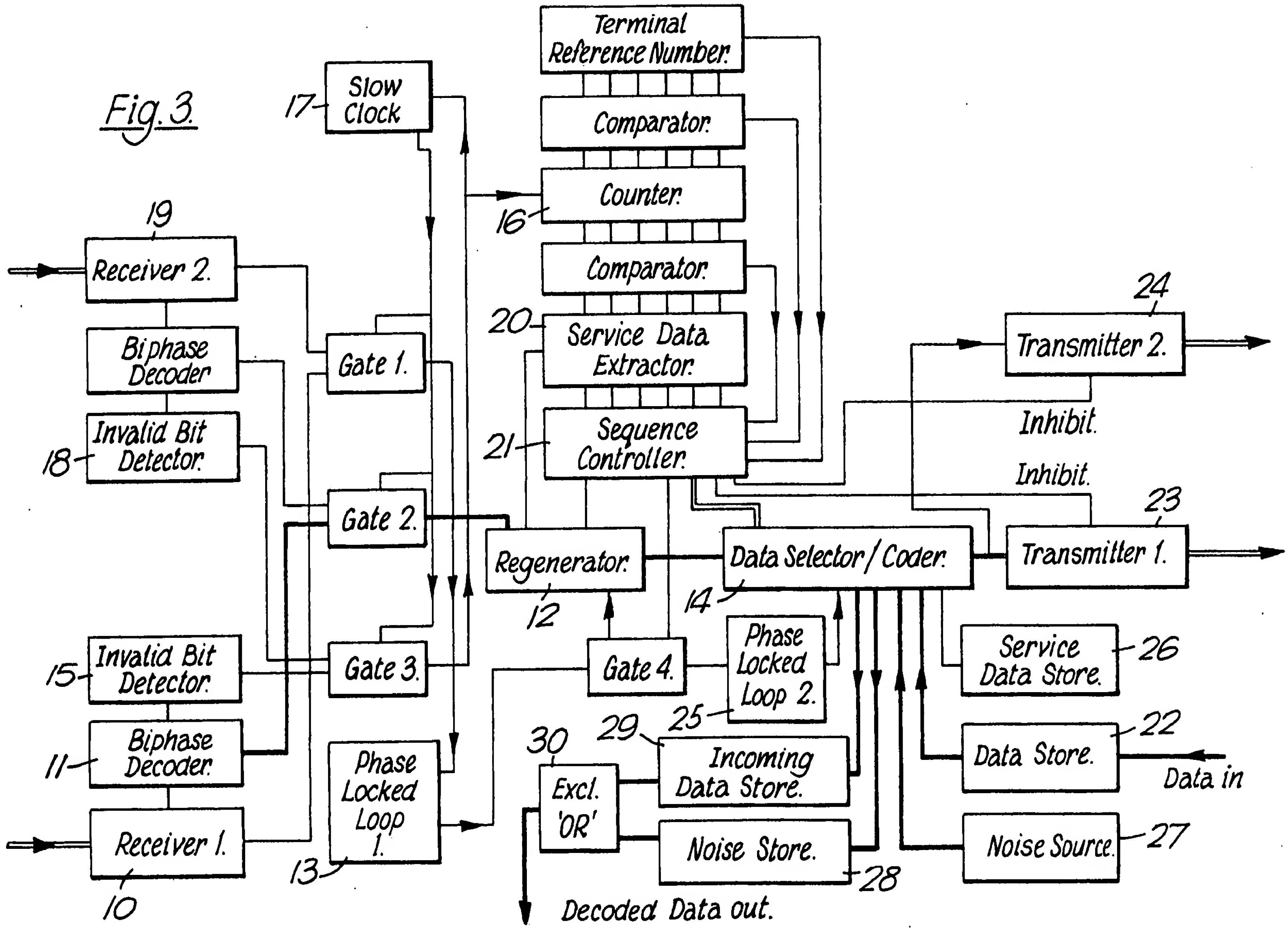


Fig. 3.


Receiver 2.
19
Biphase Decoder
Invalid Bit Detector.
18
Invalid Bit Detector.
15
Biphase Decoder.
11
Receiver 1.
10
Slow Clock
17
Gate 1.
Gate 2.
Gate 3.
Phase Locked Loop 1.
13
Terminal Reference Number.
Comparator.
Counter.
16
Comparator.
Service Data Extractor.
20
Sequence Controller.
21
Regenerator.
12
Gate 4.
Data Selector / Coder.
14
Phase Locked Loop 2.
25
Incoming Data Store.
29
Excl. 'OR'
30
Noise Store.
28
Decoded Data out.
Transmitter 2.
24
Inhibit.
Inhibit.
Transmitter 1.
23
Service Data Store.
26
Data Store.
22
Data in
Noise Source.
27

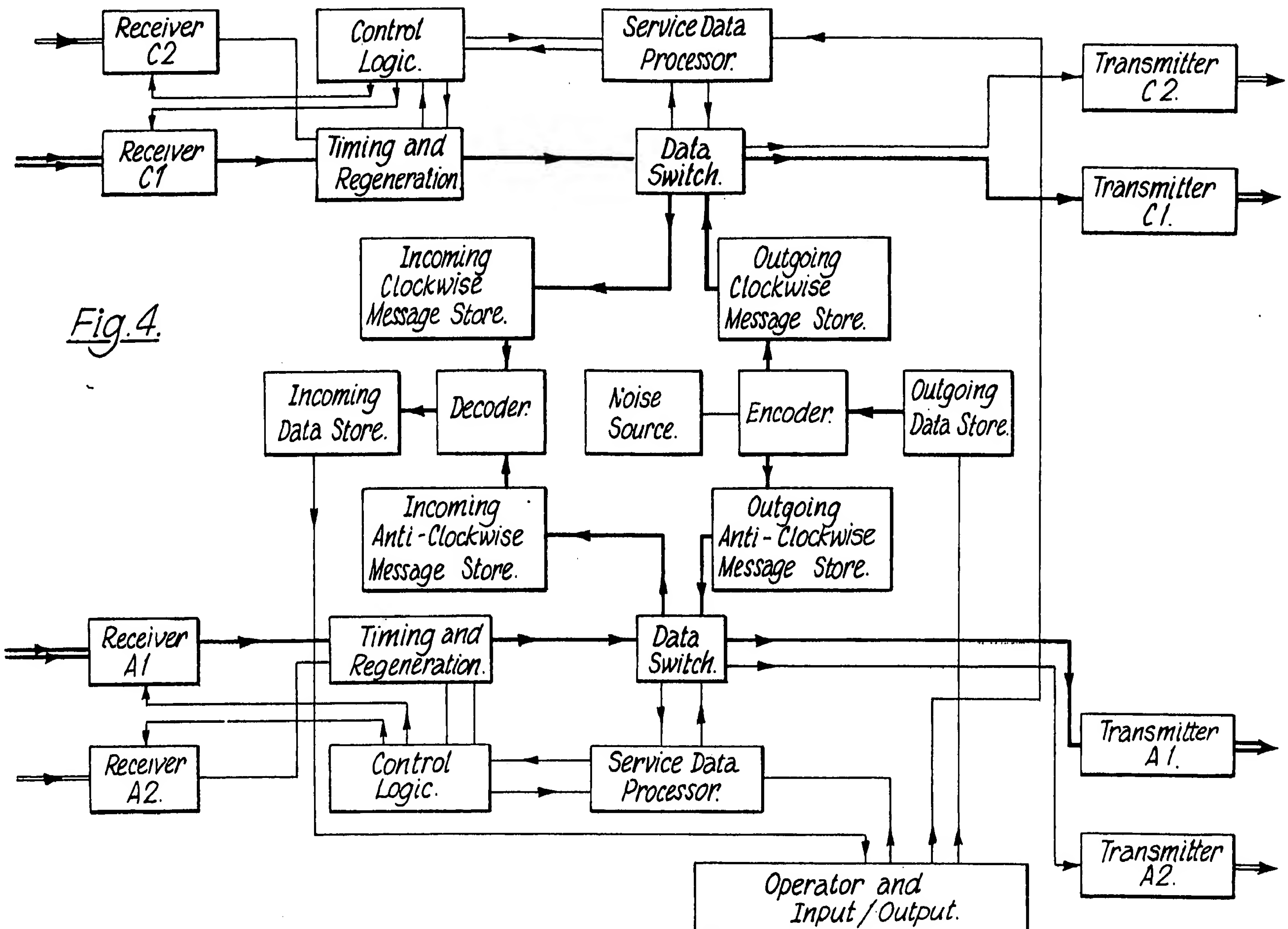
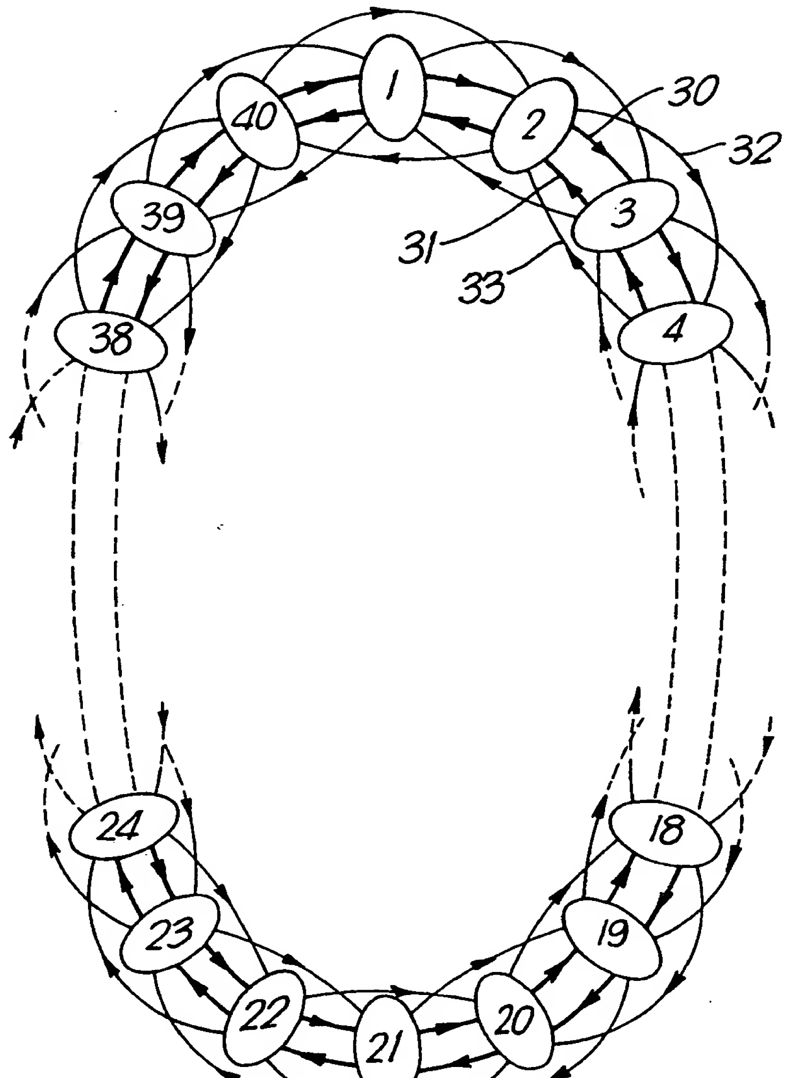

Receiver C2
Receiver C1
Control Logic.
Timing and Regeneration
Service Data Processor.
Data Switch.
Transmitter C2.
Transmitter C1.
Incoming Clockwise Message Store.
Outgoing Clockwise Message Store.
Incoming Data Store.
Decoder.
Noise Source.
Encoder.
Outgoing Data Store.
Incoming Anti-Clockwise Message Store.
Outgoing Anti-Clockwise Message Store.
Receiver A1
Receiver A2.
Timing and Regeneration.
Control Logic.
Data Switch.
Service Data Processor.
Transmitter A1.
Transmitter A2.
Operator and Input/Output.

Fig.4.

Fig.5.



SPECIFICATION

Data transmission system

This invention relates to a data transmission system of the closed-loop type, i.e. to a system of the so-called "ring main" type.

An object of the invention is to improve the security provided by such a system, especially where that security is provided by physical means rather than cryptographically.

According to the present invention there is provided a data transmission system which includes data terminals so interconnected that the system is a closed loop system, in which for each message to be conveyed from a first one of said terminals to a second one of said terminals an initial message is sent from said second terminal to said first terminal which includes service data and a randomly generated bit stream, a representation of said randomly generated bit stream being maintained in a store at said second terminal, in which at said first terminal the message to be sent is encoded with the randomly generated bit stream, in which the service data and the encoded message are transmitted from the first terminal to the second terminal with the direction of transmission the same as that used for the transmission of said initial message, and in which on reception at the second terminal the encoded message is decoded using said stored representation of said randomly generated bit stream.

The embodiments of the invention to be described herein use optical fibre transmission links, but the invention is applicable to other forms of data transmission systems, including electrical systems in which the transmission links are metallic conductors.

Embodiments of the invention will now be described with reference to the accompanying drawings, included:

Fig. 1 is a simplified diagram which explains the basic features of the invention as applied in a system in which the inter-terminal links use optical fibre conductors.

Fig. 2 explains a feature of the system terminals.

Fig. 3 is a block diagram of a terminal as used in a system such as that shown in Fig. 1.

Fig. 4 is a block diagram somewhat similar to that of Fig. 3, but for a system in which separate loops are used for two directions of transmission, i.e. a system analogous to a "four-wire" system.

Fig. 5 is an illustration of a dual ring system to which the invention is applicable.

In the system shown in Fig. 1 there are six terminals interconnected in a closed loop by optical fibre links represented by solid lines. In addition, each of the terminals is connected to the next-but-one terminal in each direction by further optical fibre links represented by broken lines. These additional links, known as leapfrog links, provide a considerable degree of redundancy in that no one break in a link can out any of the terminals out of service. In fact the ring is only effectively broken if two adjacent links fail. These additional links will be referred to further.

Data transfer in Fig. 1 occurs in the clockwise direction, and as the "leap-frog" links do not affect ring timing and operation under normal conditions they will not be discussed in detail.

We first assume that data is to be transferred from terminal 3 to terminal 1. When its time in the system cycle occurs, terminal 1 sends out a message formed by service data followed by a random coded bit stream: the service data includes the address in the system of terminal 1. This message circulates round the ring, so that each terminal is passed in sequence (the terminals now acting as simple repeaters) until the message reaches terminal 1. When this message in its travel round the ring reaches terminal 3, the random bit stream is used to encode the message which terminal 3 wishes to send to terminal 1. Hence in this case the random code is changed to randomly coded data.

Thus terminal 1, in its portion of the system cycle, sends out service data and random code, which travels round the ring until it reaches terminal 3. The service data is now repeated unchanged, but the data intended for terminal 1 from terminal 3 is coded onto the incoming random bit stream. The result of this continues along the ring to terminal 1, where it is received at one ring delay time after the message was initiated, and is thereafter decoded using the random bit stream originally sent from terminal 1.

The system now moves on from terminal 1 to terminal 2, and thus to terminal 3 and so on, until all terminals have functioned. When a message is being sent from one terminal, operations in respect of the next terminal commence before operations for the proceding terminal have finished, so that dead periods when the ring is not conveying anything useful are minimised.

Note that where there is no message to be transmitted service data plus random bit stream may go right round the ring unaltered.

As it is the terminal which eventually receives data that initiated the message, a simple way to operate the system is for the receiving terminal to ask for data from potential sources. Thus in the above example, terminal 1 might request data from potential sources, e.g. in the above example terminal 1 might ask for data from terminal 3 in the service data part of the message. Now, if another terminal, e.g. 4, has urgent data for terminal 1 which cannot wait until 1 requests it randomly, then in terminal 4's transmission time it could send a request for a random bit sequence to 1 in the service part of its message. The actual data transfer then occurs as before in 1's time slot data in the frame.

In such a single ring system, a terminal only receives data in its own transmission time slot, so there is a problem if a terminal "wishes" to receive data from two or more sources. One simple solution to this is to allocate multiple transmission time slots per terminal, and another is to receive from different terminals in rotation in successive frames.

Thus a terminal has to operate in four different modes, which involve different control and timing functions, repeat, encode data and repeat, receive, and transmit. In the first two modes the terminal takes in data and then transmit it directly or after

encoding. This must be done without distorting the bit shape and timing, since otherwise due to repetition round the ring, cumulative errors would corrupt the data. Thus a bit-synchronous system without gaps between messages can be used, in which case the receiver, regenerator and transmitter operate from a phase locked loop locked to the incoming bit stream. One difficulty here is that a signal travelling all the way round the loop will not always suffer an integral number of bits delay, and the delay may vary with time and temperature. This can be allowed for by the use of a master timing terminal with a variable delay between its receiver and the rest of the system.

Such an arrangement is simple, but the use of a master terminal is not desirable on security grounds. Hence a preferred alternative is to allow the input and output of a receiver to be unrelated in phase in that terminal's transmission period only. Note that in such an arrangement, in the transmit/receive period, see Fig. 2, the terminal is never required to repeat messages. Since received data is stored rather than repeated, a clockless biphase decoder can be used, since the distortion it introduces is not passed on.

Thus for terminals 4 and 5, see Fig. 2, an operating sequence which may occur is

(a) Terminal 4 transmits (and receives); terminal 5 repeats using the phase locked loop.

(b) Terminal 5 transmits, and 4 repeats which causes a jump in timing at the receiver of 5, which does not matter as the received data is not repeated.

(c) Terminal 5 continues to transmit while its phase locked loop locks to the new incoming timing, ready to repeat.

(d) Terminal 6 transmit and 5 repeats, using the phase locked loop timing set up in the previous period.

(e) and so on for the rest of the cycle.

Thus any one terminal sees a bit stream without breaks, so message starts and finishes must be labelled, which could be done by breaking a parity system. However, a better way is to convey the messages by biphase coding, with invalid bits (e.g. bits of the "wrong" length at message start and finish).

With the above sequence, the order of transmission from the terminals follows the direction of the bit stream, so that large dead periods are not introduced. This fixed order is useful in start up or fault conditions. Terminals do not initially "know" how to set their timing and several may start transmitting simultaneously. However, if the terminals are arranged to reset to agree with lower numbered terminals but not high-numbered ones, the ring timing quickly sorts itself out. In this case, the settling time is less than or equal to two frame periods.

The redundant "leap frog" paths shown in Fig. 1 by the broken lines ensure that system operation is maintained in spite of link breaks. Provision of redundancy in this way tends to reduce security, but this can be overcome by suitable design of a sequence controller, see below.

Developments which could make an optical system even more secure are special fibres, and the provision that all fibres could have resistant opaque layers outside the core material to increase the difficulty of tapping. Fully optical data switches and other devices would also improve security, as would the use of microprocessors for control of terminal operations.

In a typical practical single-loop system, there are 40 terminals, in which case six address bits are needed, assuming binary coding for the addresses, and a message is preceded by "To" and "From" addresses. With the invalid characters used to define message starts and ends, we get the following message structure:

(a) Three bits duration of invalid character: one positive and one negative each of 1.5 bit length.

(b) "To" address, six bits.

(c) "From" address, six bits.

(d) Auxiliary data, four bits.

(e) Message bits.

(f) Three bits duration of invalid characters for message end, once again a positive and a negative each of 1.5 bit length.

The above arrangement, with biphase coding, also known as Manchester coding, gives a balanced signal and the invalid characters do not upset the decoders.

We now refer to Fig. 3, which shows a terminal for use in a single loop system: this has two receivers and two transmitters because of the use of leap-frog links as described above with reference to Fig. 1. For most of the system's cycle or frame, the terminal operates as a repeater, in which mode the incoming signal is detected in the first receiver 10, decoded in the biphase decoder 11 and passed via gate 2 to a regenerator 12 controlled by a phase locked loop 13. After regeneration the signal passes through the data selector 14 to the transmitters 1 and 2.

As each message passes through, the invalid bit detector 15 recognises the message end characters, and each time one passes, counter 16 is incremented and a further cycle of a slow clock 17 is inhibited. If no message end characters from receiver 10 are recognised, something is wrong, so the clock 17 is not inhibited and it increments the counter 16 after little or more than one message period. If the invalid bit detector 18 of the other receiver 19 was still detecting message end bits, the gates shown are suitably set to switch the terminal to the receiver 19, and an alarm is operated to indicate a fault condition.

The service data extractor 20 operates continuously on the basis of information which it receives from the regenerator 12, and in addition it checks each incoming address, the "from" address being checked with the counter contents. If the extractor 20 sees its own "to" address, i.e. the message is for its own terminal, it signals the fact to the sequence controller 21. This causes data to be sent out from this terminal from a data store 22, and this data is coded with the random part of the incoming message in an EXCLUSIVE OR gate. This gate is in the data selector-coder 14, from which the coded message passes to the transmitters 23, 24. In this mode the terminal acts as a repeater except that the random part of the message is retransmitted having been changed by the data.

All messages are sent out by both transmitters,

unless the "to" address is that of the next terminal, in which case the sequence controller 21 inhibits transmitter 2, the one for the "leap-frog" link. This is necessary to ensure that a message does not circulate too far round the ring. This would otherwise weaken security by allowing an encoded message and its random code to be present in the same proximity.

Eventually, as the stream of messages passes through the terminal, the counter 16 reaches the terminal's own number, and when this occurs, the sequence controller 21 causes the following operations:

(a) Gate 4 between the two phase-locked loops 13 and 25 opened.

(b) The two transmitters 23 and 24 are connected by the data selector 14 first to the service data store 26 and then to the output of the random noise source 27. This later supplies the random portion of the next message to be sent out from the terminal. The timing of the outgoing random bit stream is controlled by the second phase-locked loop 25, and as the random bit stream goes out it is also fed into a temporary store 28.

(c) After one ring delay, the terminal receives the service data which it originated, and which contains its own "from" address. The bit stream after the service data is then (if there was a message destined for this terminal) the originally transmitted random bit stream (derived from the noise source) after encoding with data. This portion of the incoming bit stream is routed from the data selector 14 into the incoming bit store 29. At a later time this data is extracted again and fed to an EXCLUSIVE OR gate 30 but in phase with a read out of the non-coded random stream in the store 28. The output of the EXCLUSIVE OR gate 30 is the wanted data, decoded from the encoded data as received by the terminal.

In this case the timing of the incoming bit stream, after it has circulated round the ring, is not the same as that of the previously received message. Hence the phase-locked loop 13 needs time to settle and the regenerator 12 may not operate correctly. However, the incoming message is not regenerated and sent out again, and it is decoded correctly. Small bit timing errors are of no significance as they are not passed on.

In the steady state, the terminals increment their counters when the invalid characters at the beginnings and ends of the messages are recognised, such that the number in a terminal's counter is that of the received "from" address in the next time slot. On start up or after a fault the counter setting does not agree with the "from" address, and to decide which timing information to believe, the following technique is used:

(a) terminals increment their counters if no message is received for a preset period slightly greater than the maximum message length.

(b) terminals reset their counters to agree with incoming "from" addresses if the address is *less than* the contents of the counter, but *not* if the "from" address is greater than the counter contents.

The second exclusion ensures that it is not possible for more than one message to exist steadily in the ring.

With such a sequence it is found that the system fairly quickly reaches a stable operating condition.

We now turn to Fig. 4, which shows a terminal for a system with a dual ring, one loop for clockwise transmission and the other for anti-clockwise transmission. The dual ring performs a similar task to the single ring, but its electro-optics are more complex. In the dual ring, terminals originate their own random sequence and data, and both are sent out in the terminal's transmission time slots. Thus only one message may be sent out from a terminal per frame, but any number of messages may be received, depending on a terminal's storage capacity. This contrasts with the single ring system in which any number of messages may be sent by a terminal in one frame, but only one received.

Another difference of the dual ring system from the single ring is that if all fibres at some point on the ring, including leap frog links, were broken, both clockwise and anti-clockwise paths would still exist. Hence full intercommunication is still feasible, though without the random coding.

Fig. 5 shows the dual ring arrangement, in which the ovals, each of which contains a number, are the terminals. The heavy lines such as 30, 31 are main signals paths and the lighter lines such as 32, 33 are leap frog signal paths.

Unless dead periods are allowed between messages on a ring, the order in which the terminals transmit must follow the direction of transmission of data. Thus on a dual ring with clockwise and anti-clockwise paths, messages in each direction may not be transmitted simultaneously, e.g. transmissions could occur in the order (see Fig. 5):

Clockwise	*Anti-clockwise*
1	1
2	6
3	5
4	4
5	3
6	2
1	1
2	6 and so on.

For most timing purposes the dual ring can be regarded as two single rings, but the rings have to be tied together at some point so that their timings do not gradually drift apart.

A dual ring terminal sends two bit sequences at different times during the frame for each message, and also receives two bit sequences at different times for every incoming message.

Thus four data stores are needed to enable a terminal and receive one message per frame, and two more stores are needed for each additional received message.

In view of the fairly detailed description already given of the single ring terminal it is felt that no further description of Fig. 4 is needed, except to point out that each block thereof which is labelled "Service Data Processor" corresponds to several blocks in Fig. 3. In fact, microprocessors could be used here.

In the system described above the inter-terminal links are optical fibre links so that each receiver is an opto-electrical transducer, e.g. based on a photodiode, while each transmitter is an electrical-optical transducer, e.g. base on a laser. As already mentioned, the invention is also applicable to fully electrical systems.

CLAIMS

1. A data transmission system which includes data terminals so interconnected that the system is a closed loop system, in which for each message to be conveyed from a first one of said terminals to a second one of said terminals an initial message is sent from said second terminal to said first terminal which includes service data and a randomly generated bit stream, a representation of said randomly generated bit stream being maintained in a store at said second terminal, in which at said first terminal the message to be sent is encoded with the randomly generated bit stream, in which the service data and the encoded message are transmitted from the first terminal to the second terminal with the direction of transmission the same as that used for the transmission of said initial message, and in which on reception at the second terminal the encoded message is decoded using said stored representation of said randomly generated bit stream.

2. A system as claimed in claim 1, and in which when a terminal has a message to send to another terminal it sends via the loop to said other terminal a request for a said initial message, whereafter the system functions in the manner set out in claim 1.

3. A system as claimed in claim 1, in which the system functions in a time divided manner with each said terminal allocated a time slot in the system's cycle at which it can emit a said initial message, and in which on each occurrence of a terminal's time slot a said initial message is transmitted therefrom with a view to a check to see if any other terminal has a message for that one of the terminals.

4. A system as claimed in claim 1, 2 or 3 in which the closed loop to which each said terminal is connected includes two sets of inter-terminal links, one set referred to as the main links and the other set referred to as leap-frog links, in which each said main link interconnects two adjacent links and each said leap-frog link interconnects one terminal and the next-but-one terminal in the loop, and in which each message which leaves a said terminal is sent thereform both over the main link and the leap-frog link which leave that terminal, unless the message is for the next terminal in which case transmission over the leap frog link is inhibited and the message is sent only on the main link.

5. A system as claimed in claim 3 or claim 4 with claim 3, in which the messages are conveyed using biphase coding so that line current is substantially balanced, and in which message starts and message ends are each marked by a plurality of message elements each of which is recognisably different, e.g. by its greater length, to the message bits.

6. A system as claimed in claim 1, 2, 3, 4 or 5, and in which the system has two loops on one of which messages are conveyed clockwise while on the other they are conveyed anti-clockwise.

7. A system as claimed in claim 1, 2, 3, 4, 5, or 6 and in which the links of the loop or loops are metallic conductors.

8. A system as claimed in claim 1, 2, 3, 4, 5, or 6, and in which the links of the loop are optical fibre links.

9. A data transmission system substantially as described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1980.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.